National Transportation Safety Board
Office of Highway Safety
Washington, DC 20594

HWY24MH001

VEHICLE FACTORS

Group Chair's Factual Report

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A. CRASH INFORMATION

Location: Etna, Licking County, Ohio
Date: November 14, 2023
Time: 8:47 a.m. EST

B. VEHICLE FACTORS GROUP

Group Chair	Jerome Cantrell National Transportation Safety Board Washington, DC
Group Member	Ritchie Huang Daimler Truck North America Portland, OR

C. CRASH SUMMARY

For a summary of the crash, refer to the *Crash Information and Summary Report*, which can be found in the NTSB docket for this investigation.

D. DETAILS OF THE INVESTIGATION

The Vehicle Factors Group Chair's Factual is a collection of factual information obtained during the detailed inspection of the 2019 Freightliner truck-tractor in combination with a 2017 Strick semitrailer, and the 2009 Van Hool motorcoach. Photographs and damage descriptions were obtained for the 2015 Nissan Murano SUV and 2006 Toyota Highlander. The 2014 Volvo truck-tractor and 2022 Vanguard semitrailer combination were released by the Ohio State Highway Patrol (OSHP) prior to the arrival of NTSB investigators and were not available for examination. All examinations of the crash vehicles were conducted at Jae's Towing and Recovery facility, located in Heath, OH between November 15 and 20, 2023.

The electronic control module (ECM) and common powertrain controller (CPC) were removed from the Van Hool motorcoach, and the steering gear box was removed from the 2019 Freightliner truck-tractor. All items were placed into evidence by the Ohio State Highway Patrol (OSHP) and released to the NTSB for further examinations. At the conclusion of the component examinations, the components were returned to the OSHP.

For uniform description, "left" will refer to the driver's side, and "right" will refer to the passenger/curbside of the vehicle.

1.0 Vehicle Examinations

1.1 2019 Freightliner Truck-Tractor

Make:	Freightliner
Model:	Cascadia
VIN:[1]	3AKJHHDR4KSKJ3441
Model Year:	2019
Date of Manufacture:	November 2018
Placed into Service:	December 2018
Mileage:	Unknown
GVWR:[2]	52,350 lbs.
GAWR[3] (Axle 1):	12,500 lbs.
GAWR (Axle 2):	20,000 lbs.
GAWR (Axle 3):	20,000 lbs.
Engine:[4]	Detroit Diesel DD15, 14.8L / 475 HP
Fuel Tanks:	(2) 120-gallon aluminum fuel tanks
DEF Tank:[5]	23-gallons
Transmission:	DT12-1650 12-speed, Automated Manual
Rear Axle Ratio:	2:85
Steering Gear:	TRW/ZF THP-60054A, SN: U2735
Brake Type:	Air-operated drum brakes with WABCO 4S/4M Antilock Braking System (ABS)

1.2 Freightliner Damage Description

The 2019 Freightliner Cascadia truck-tractor (truck-tractor) was completely burned from the post-crash fire. All combustible materials from the front bumper to rear of the last drive axle, such as the electrical wiring, rubber and plastic air hoses and lines, all driver controls, and vehicle body parts were damaged – See **Figure 1**.

[1] Vehicle Identification Number.
[2] Gross Vehicle Weight Rating (GVWR) is the total maximum weight that a vehicle is designed to carry when loaded, including the weight of the vehicle itself, plus fuel, passengers, and cargo.
[3] Gross Axle Weight Rating (GAWR) is the maximum distributed weight that a given axle is designed to support.
[4] Information obtained from Freightliner order specifications.
[5] Diesel Exhaust Fluid.

Figure 1 – 2019 Freightliner Truck-Tractor.

The front frame horns and rails were bowed upward and rearward. The right-side frame rail was bowed outward above the steering axle, and the left-side frame rail was buckled outward and bowed upward above the steering axle. The right-side frame rail was bowed upward beneath the sleeper berth. The cab was separated from the front and rear mounts.

Damage to specific areas and operational components will be discussed later in this report.

1.3 Weights and Measurements

Due to the significant crash and post-crash fire damage, the actual weight of the subject truck-tractor was not obtained. Freightliner is a brand of Daimler Truck North America (Daimler). Daimler provided the following information for the subject truck-tractor. The weights indicated were taken from the scaled weight taken at the manufacturing facility.

- Front axle weight: 10,426 lbs.
- Rear axle weight: 7,755 lbs.
- GVWR: 52,350 lbs.
- Wheelbase: 227 inches
- Vehicle length: 320 inches

1.4 Powertrain

The engine, batteries, and electrical cables and wires sustained extensive crash and post-crash fire damage. The fluid cooling radiators for the engine, transmission, and air conditioning all sustained crash and post-crash fire damage. All water, hydraulic, and air hoses were consumed by the post-crash fire. Both diesel fuel tanks were missing from the truck-tractor but were later located with the other crash and scene clean-up debris. Both tanks exhibited some thermal damage along with being torn open and crushed.[6]

The propeller shaft, which transferred torque from the engine and transmission combination to the drive axles, consisted of three pieces. The forward shaft was connected to the rear of the transmission and the intermediate shaft at the carrier bearing. The intermediate shaft went from the forward shaft connection to the pinion gear shaft at the front drive axle. The short rear propeller shaft was connected to the rear of the front drive axle and the pinion gear shaft on the rear drive axle. The propeller shafts remained attached to their respective attachment locations. The forward propeller shaft was bowed. Neither drive axle housings exhibited any crash damage other than burn marks from the post-crash fire. The left side of the front drive axle was displaced rearward.

1.5 Driver Controls

All the driver controls, gauges, and switches were consumed by the post-crash fire. The truck-tractor was equipped with the standard electronic cruise control with intelligent powertrain management (IPM) and an electronic accelerator control pedal.[7]

An IPM system is standard on vehicles equipped with the DT12 transmission. The function of an IPM is to aid in fuel efficiency by predicting the proper vehicle speed and gear selection for upcoming road grades. This is accomplished by utilizing a 3D digital map database and GPS. Cruise control must be engaged for IPM to be active. IPM has default variance of +5/4 mph and will automatically activate the engine brake if the vehicle exceeds the set cruise speed. When the vehicle is being operated on a roadway that is not included in the 3D map database, the systems revert to a conventional cruise control system.[8]

On the left-side steering wheel pod, there would have been push buttons to navigate through the digital instrument cluster. On the right-side steering wheel pod,

[6] See Vehicle Attachment – Vehicle Examination Photographs
[7] See Vehicle Attachment – 2019 Freightliner Build Sheets
[8] Intelligent Powertrain Management (IPM) - Public Technical Literature (dtnatechlit.com)

there would have been push buttons to operate the cruise control, hands-free calling, and the ability to flash the headlamps and marker lights.

There would have been a multifunction turn signal switch mounted to the left-side of steering column. In addition to the turn signals, the driver could operate the windshield wipers and the high beam and low beam setting for the headlamps.

Mounted on the right side of the steering wheel column would have been the transmission multifunction control lever.

With this lever the driver could operate the transmission in either manual or automatic shift modes. The up and down position of the lever also controlled the level of engine braking.

1.6 Electrical System

The wiring, lighting components, and batteries were consumed by the post-crash fire. The truck-tractor was equipped with multiple control modules for engine management and vehicle operations which were consumed by the post-crash fire as well.

1.7 Steering System

The truck-tractor was equipped with a tilt/telescoping steering column, upper and lower steering shafts, a hydraulic assisted power steering gearbox with a remotely mounted hydraulic reservoir, a pitman arm, a drag link, steering knuckles, and a tie rod.

The steering system was intact, but not functional. The post-crash fire consumed the driver controls which would have been mounted to the steering wheel, leaving just the metal steering wheel ring. The steering shafts remained connected from the steering wheel to the input shaft of the steering gear box. The tie rod connecting the left and right steering knuckles was bowed.

The steering gear box was removed from the truck-tractor and taken to ZF North America, Inc., by NTSB and the Public Utilities Commission of Ohio (PUCO). The steering gear box was disassembled and examined by ZF engineers while being observed by the NTSB investigator. The steering gear housing displayed discoloration and rust, but no crash damage. The input shaft had been pushed inside the housing, and the shaft felt loose and unable to be rotated by hand. The steering gear housing was disassembled to facilitate the examination of the internal gears. The sector shaft, worm gear, 32 recirculating balls, and thrust washers were removed and examined.

The sector shaft had a broken tooth along with some brinelling marks.[9] There were also brinell marks on the worm gear and thrust washers. The external ring for the bearing assembly was broken and no longer intact.[10] Examining the damaged components, and where the damaged was located on the components, it was determined that the orientation of the steering gear was in a straight-forward direction at impact.

1.8 Suspension System

The suspension on the steering axle (axle 1) consisted of single-leaf springs, shock absorbers, and a solid axle. The rubber grommets were missing from the shock absorbers. The spring eye bushings sustained thermal damage.

The suspension on the drive axles (axle 2 and axle 3 respectively) consisted of single-leaf springs, air springs, shock absorbers, and solid axles. Both spring hangers for axle 2 suspension were melted, allowing the spring eyes to become separated from the hangers. The axle 3 right-side spring hanger was cracked above the spring eye mounting location. All air springs and shock absorber rubber grommets were consumed by the post-crash fire.

1.9 Brake System

The combustible materials, such as brake hoses, airlines, s-cam bushings, and brake chamber diaphragms, for the air brake system were consumed by the post-crash fire. This damage prevented any brake adjustment or operational checks to be conducted. The end caps that housed the parking brake return springs were missing from the brake chambers mounted to both drive axles. The remaining brake components were examined, and that information is in **Table 1**.

Table 1: Truck-Tractor Brake Information[11]

Brake Location	Axle 1		Axle 2		Axle 3	
	Left	Right	Left	Right	Left	Right
Brake Type[12]	Wabco 24L Drum	Wabco 24L Drum	Wabco 30/36 Drum	Wabco 30/36 Drum	Wabco 30/36 Drum	Wabco 30/36 Drum
Pushrod Stroke (Inches)	NA	NA	NA	NA	NA	NA
	Upper: 18/32nds	Upper: 17/32nds	Upper: 21/32nds	Upper: 16/32nds	Upper: 26/32nds	Upper: 26/32nds

[9] Brinelling marks are indentations left on a hard surface after impact with another hard surface.
[10] See Vehicle Attachment – Steering Gear Examination Report.
[11] All measurements are in inches.
[12] All brakes were long stroke.

Measured Lining Thickness[13]	Lower: 18/32nds	Lower: 18/32nds	Lower: 21/32nds	Lower: 19/32nds	Lower: 25/32nds	Lower: 26/32nds
Drum Measurement	16.11	16.14	16.02	16.11	16.14	16.10
Manufacturer's Specification – Maximum Inside Drum Measurement	16.620	16.620	16.620	16.620	16.620	16.620

1.10 Tires and Wheels

The manufacturer's specification plate was consumed by the post-crash fire. Generally, the manufacturer's label contains information specific to the vehicle identification number assigned to this vehicle, which includes specified tire and wheel information. The truck-tractor was originally equipped with 295/75R22.5 14 ply tires on all axles.[14]

General information about each of the tires on the truck-tractor at the time of the inspection is documented in the **Table 2**. All ten (10) tires were consumed by the post-crash fire with the exception of some tread on the drive axles. All the wheels were inspected for cracks, welds, and elongated lug nut holes. No non-crash related defects were discovered on any of the wheels.

Table 2: Truck-Tractor Tire Information

Axle 1	**Left**		**Right**	
Make/Model	NA		NA	
Tire Size	Unknown		Unknown	
Pressure	Unknown		Unknown	
Tread Depth[15]	Unknown		Unknown	
DOT #	Unknown		Unknown	
Maximum Load Rating[16]	Unknown		Unknown	
Tire Plies	Unknown		Unknown	
Wheels	Cast: 22.5x8.25		Cast: 22.5x8.25	
Axle 2	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Make/Model	Missing	NA	NA	Missing
Tire Size	Unknown	Unknown	Unknown	Unknown
Pressure				

[13] Minimum allowable lining thickness is ¼ inch (8/32nds) (49*CFR*393.47(d)(2)
[14] See Vehicle Attachment – 2019 Freightliner Build Sheets
[15] Measurements were taken from the outboard to inboard. Measurements are in 32nds.
[16] This is the maximum weight this size tire can carry in a single tire configuration.

Tread Depth	Unknown	28,31,31,31 (9-inch tread patch)	27,30,30,27 (6-inch tread patch)	Unknown
DOT #				
Maximum Load Rating[17]	Unknown	Unknown	Unknown	Unknown
Tire Plies	Unknown	Unknown	Unknown	Unknown
Wheels	Steel: 22.5x8.25	Steel: 22.5x8.25	Steel: 22.5x8.25	Steel: 22.5x8.25
Axle 3	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Make/Model	NA	NA	NA	Missing
Tire Size	Unknown	Unknown	Unknown	Unknown
Pressure	Unknown	Unknown	Unknown	Unknown
Tread Depth	28,30,30,30 (23-inch tread patch)	28,30,30,30 (5-inch tread patch)	30,31,31,30 (13-inch tread patch)	Unknown
DOT #	Unknown	Unknown	Unknown	Unknown
Maximum Load Rating[18]	Unknown	Unknown	Unknown	Unknown
Tire Plies	Unknown	Unknown	Unknown	Unknown
Wheels	Steel: 22.5x8.25	Steel: 22.5x8.25	Steel: 22.5x8.25	Steel: 22.5x8.25

1.11 Anti-Lock Braking System (ABS)

All ABS sensors, wiring, and modulators were consumed by the post-crash fire.

1.12 Electronic Control Module (ECM) Data Download

The ECM, which was mounted to the left-rear of the engine, and other control modules, which were mounted inside the cab – forward of the passenger seat, were consumed by the post-crash fire.

1.13 Collision Avoidance System Technologies

This section highlights Collision Avoidance Systems (CAS) that are designed to aid in the prevention of frontal offset crashes. Although some of these technologies were available, currently there are no federal regulations requiring the installation of these systems. According to the carrier that owned the Freightliner in this crash, the truck was ordered using prior years specification order sheets.[19] Although the Freightliner was equipped with the latest engine and transmission configurations, the

[17] This is the maximum weight each tire can carry when mounted in a dual tire configuration.
[18] This is the maximum weight each tire can carry when mounted in a dual tire configuration.
[19] See Vehicle Factors Attachment – Mid State Systems Interview Transcript.

order sheets had not been updated or modified to include any of the latest collision avoidance technologies. The carrier did not discuss CAS technology with the manufacturer at the time of purchase.

A collision avoidance system is a suite of technologies designed to prevent or reduce the severity of a crash before it occurs. These technologies are also referred to as Advanced Driver Assistance Systems (ADAS). ADAS employs various technologies, including RADAR (radio detection and ranging), cameras, and LIDAR (light detection and ranging) systems, to monitor the environment for potential conflicts that could lead to a crash, such as a sudden lane change and slow-moving or stopped vehicles. An ADAS monitors the forward environment. When the ADAS detects a conflict, it begins to prepare the brakes and sends a warning to the driver. Warnings can be auditory, visual, or haptic. In some cases, the system can also prepare the occupant restraint system to improve protection if a crash occurs.

As of 2018, Freightliner Cascadia's were built with a suite of ADAS that were offered as standard equipment. The version of the Detroit Assurance Safety Suite being offered at the time of the crash was version 5.0, which included the following collision mitigation hardware and software: a) active brake assist, b) adaptive cruise control, and c) lane departure warning. Active brake assist utilizes multiple short- and long-range radars and a windshield mounted camera. The signals from the radars and camera are fused for greater object recognition to provide enhanced braking capabilities.[20] Adaptive cruise control automatically adjusts vehicle speed to maintain a safe following distance from a forward vehicle. The following distance of between 2.4 and 3.6 seconds can be adjusted by the driver. Adaptive cruise control can bring the vehicle to a complete stop, if necessary, in stop-and-go traffic. The Detroit Assurance Safety Suite version 5.0 has the capability to incorporate additional systems which are listed as optional. The optional systems consist of active lane assist technology which includes lane departure warning, lane keep assist technology, side guard assist technology, traffic sign recognition, automatic wipers and headlights, and intelligent high beam.

Detroit Assurance Safety Suite version ABA6, which was announced on October 15, 2024, improves on the version 5.0 by adding side guard assist 2, front guard alert, along with these optional features active lane assist 2, active side guard assist, a driver facing camera, traffic sign display with warnings, and active speed intervention. Detroit Assurance Safety Suite ABA6 is not scheduled for release to the consumer until 2025.

A driver-monitoring system (DMS), also known as a driver state sensing (DSS) system, is an advanced safety feature found in some modern passenger vehicles. Its primary goal is to issue warnings or alerts when it detects signs of driver inattention or fatigue, redirecting the driver's attention back to the task of driving.

[20] Information obtained from Detroit Assurance: New Features | Detroit

A DMS works by utilizing a driver-facing camera equipped with infrared light-emitting diodes (LEDS) to see the driver's face and eyes. If the system detects the driver is drowsy or distracted, it can issue audio alerts, illuminate a visual indicator, provide haptic warnings, and in cases where there is an imminent crash, the system may automatically apply the brakes.

Although DMS was not available from Daimler at the time this truck-tractor was manufactured, Daimler Trucks North America offers Attentive Driver Protection in the ABA6 version of the Detroit Assurance Safety Suite. According to Daimler, Attentive Driver Protection helps protect the driver and surrounding traffic in the unlikely event the driver becomes unresponsive, actively bringing the truck to a stop while keeping it centered in its lane and turning on the hazard lights. [21]

For Daimler truck-tractors manufactured prior to this latest technology or ordered without it, or manufactured by a different OEM, a DMS is available from third party venders and can be retrofitted into existing vehicles. These third-party systems are able to monitor the driver, but not activate the vehicle's braking systems.

Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) technologies are generally referred to as connected vehicle technology. This technology is being designed to allow vehicles to communicate with each other regarding traffic flow, braking actions, and turning movements at a minimum. This technology will also allow the vehicles to interpret road signs and receive messages from changing message boards. This technology was not available for large-scale distribution at the time of this report.

1.14 Maintenance Records / Recalls

The maintenance completed on the truck-tractor, according to the maintenance records from 11/30/2022 through 10/24/2023, is listed below. The last annual inspection was conducted in May 2023, and listed no defects.

- 11/30/2022 Replaced wiper motor
- 1/28/2023 Oil change and lubrication, replaced coolant return line (444,188 miles)
- 3/19/2023 Replaced light plug and headlamp
- 5/12/2023 Vehicle lubrication/inspection (477,788 miles)- no issues
- 5/12/2023 Oil change and lubrication, replaced air compressor and air dryer (477,788 miles)
- 5/22/2023 replaced air line
- 6/29/2023 Replaced right hood mirror and a couple of body panels

[21] Detroit Assurance: New Features | Detroit

- 7/17/2023 Replaced wheel seal, replaced 4 brakes, and adjusted brakes
- 7/25/2023 Replaced NOx sensor
- 8/4/2023 Replaced NOx sensor
- 8/14/2023 Replaced wheel seal
- 8/25/2023 Replaced brake switch, wiring harness, and manifold
- 9/9/2023 Repair air hose
- 10/13/2023 Vehicle lubrication/inspection (522,476 miles) – no issues
- 10/13/2023 Oil change and lubrication, replaced steer tires (522,476 miles)
- 10/18/2023 Replaced bad DEF pump
- 10/24/2023 Replaced NOx Sensor
- 10/25/2023 Checked air in tires
- 11/4/2023 Replaced 4 tires and wheels (527,107 miles)

The manufacturer provided two recalls that were associated with this vehicle. There are no records regarding if these recalls were completed.

- Recall FL893A-G issued February 2022: This recall pertained to the replacement of aluminum battery cables with copper battery cables.
- Recall FL922A-C issued May 2022: This was an emissions recall replacing the exhaust pipe between the turbocharger outlet and the aftertreatment system inlet.

2.0 2017 Strick Semitrailer

Make:	Strick Commercial Trailer
Model:	53’ Dry Van
VIN:	1S12E9531HE533288
Date of Manufacture:	November 2015
Placed into Service:	Unknown
GVWR:	65,000 lbs.
GAWR (Axle 1):	20,000 lbs.
GAWR (Axle 2):	20,000 lbs.
Brake Type	Air-operated drum brakes with ABS

2.1 Damage Description

The front portion of the semitrailer was missing along with the king pin and upper fifth wheel plate. As seen in **Figure 2,** all that remained at the front of the semitrailer were the vertical ribs and roof rails. The vertical ribs were bowed forward, and there are pieces of the semitrailer located on the deck of the truck-tractor. There were remnants of batteries and semitrailer pieces located on the truck-tractor at the

tow yard. The complete exterior skin of the semitrailer was consumed by the post-crash fire – See **Figure 3**. From the landing gear to the rear bumper, the cargo floor and the components below the floor remained intact with limited damage.

Figure 2 The front of the semitrailer at the crash scene. (Courtesy of the OSHP)

Figure 3 – 2017 Strick Semitrailer.

2.2 Electrical System

The electrical system sustained crash and post-crash fire damage. The only lighting devices that remained intact were the rear tail lamps and turn signals. The lights were light emitting diodes (LED)s.

2.3 Suspension

The suspension mounted to the axles on the semi-trailer (axles 4 and 5 respectively) consisted of pivot control beams, air springs, and solid axles. There was no crash or post-crash fire damage sustained to either axle suspension.

2.4 Brake System

The brake system was examined, and push rod stroke measurements were taken. During on-scene recovery, the brakes were caged to prevent changes to the brake adjustments to occur. The brake air system was connected from a service truck to the service and emergency brake air hoses forward of axle 4. The air pressure was regulated at 90 psi for the push rod stroke measurements. From the center of the semitrailer rearward, there was no crash or post-crash fire damage sustained by the brake system. The specifics of the brake system examination are listed in **Table 3**.

Table 3: Strick Semitrailer Brake Information[22]

Brake Location	Axle 1		Axle 2	
	Left	Right	Left	Right
Brake Type - Drum	Ranger Brake Products 30/30	Ranger Brake Products 30/30	Ranger Brake Products 30/30	Ranger Brake Products 30/30
Pushrod Stroke	2	2	2	1 ¾
Measured Lining Thickness	Upper: 25/32nds	Upper: 17/32nds	Upper: 18/32nds	Upper: 16/32nds
	Lower: 25/32nds	Lower: 20/32nds	Lower: 21/32nds	Lower: 18/32nds
Inside Drum Measurement	16.02	16.17	16.32	16.21
Manufacturer's Specification – Maximum Inside Drum Measurement	16.62	16.62	16.62	16.62

[22] All measurements are in inches.

2.5 Tires and Wheels

The manufacturer's specification plate was missing from the front of the semitrailer. Information obtained from the vehicle manufacturer stated the tire and wheel sizes recommended by Strick and originally equipped on the crash-involved trailer were 295/75R22.5 and 8.25 X 22.5 respectively.

General information about each of the tires on the semitrailer at the time of the inspection is documented in **Table 4** below. All the wheels were inspected for cracks, welds, and elongated lug nut holes. There were no non-crash related defects discovered on any of the wheels. Tire pressure measurements were taken using a commercial grade tire pressure gauge.

Table 4: Semitrailer Tire Information

Axle 1	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Make/Model	Hankook DH37	Firestone FD691	Cooper Pro Series	Firestone FD691
Tire Size	295/75R22.5	295/75R22.5	295/75R22.5	295/75R22.5
Air Pressure	102 psi	108 psi	102 psi	104 psi
Tread Depth	10,10,9,9	10,9,9,10	10,11,11,11	10,10,10,10
DOT #	Recap# FDK0722	W1BT3J74814	Recap# FDK0423	Recap# FDK0423
Maximum Load Rating[23]	5,675 @ 110 psi - Dual	5,675 @ 110 psi - Dual	5,675 @ 110 psi - Dual	5,675 @ 110 psi - Dual
Tire Plies	Tread: 5-steel Sidewall: 1-Steel	Tread: 5-steel Sidewall: 1-Steel	Tread: 5-steel Sidewall: 1-Steel	Tread: 5-steel Sidewall: 1-Steel
Wheels	Steel: 22.5x8.25	Steel: 22.5x8.25	Steel: 22.5x8.25	Steel: 22.5x8.25
Axle 2	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Make/Model	Firestone FD691	Bridgestone M710	Firestone FS591	Hankook DL11
Tire Size	295/75R22.5	295/75R22.5	295/75R22.5	295/75R22.5
Air Pressure	106 psi	102 psi	102 psi	104 psi
Tread Depth	8,7,7,8	11,10,10,10	7,7,7,7	6556
DOT #	W18T3J74616	Recap# RDRY1820	4DBT65N0322	5MD2PPH3118
Maximum Load Rating	5,675 @ 110 psi - Dual	5,675 @ 110 psi - Dual	5,675 @ 110 psi - Dual	5,675 @ 110 psi - Dual
Tire Plies	Tread: 5-steel Sidewall: 1-Steel	Tread: 5-steel Sidewall: 1-Steel	Tread: 5-steel Sidewall: 1-Steel	Tread: 5-steel Sidewall: 1-Steel
Wheels	Steel: 22.5x8.25	Steel: 22.5x8.25	Steel: 22.5x8.25	Steel: 22.5x8.25

[23] This is the maximum weight each tire can carry when mounted in a dual tire configuration.

The outside tires mounted on the right side of axles 1 and 2 contained light roadway abrasions in the tread areas. All the outside-mounted tires were covered with melted material from the post-crash fire. There was no additional pre-crash or crash related damage identified to the semitrailer tires or wheels.

2.6 Anti-Lock Braking System (ABS)

All ABS sensors, wires, and modulators were intact and in place – no defects were observed.

3.0 2009 Van Hool Motorcoach:

Make:	Van Hool
Model:	C2045
VIN:	YE2CC17B392047581
Model Year:	2009
Date of Manufacturer:	September 2008
Mileage:[24]	186,841
GVWR:	50,700 lbs.
GAWR (Axle 1):	16,500 lbs.
GAWR (Axle 2):	24,250 lbs.
GVWR (Axle 3):	15,000 lbs.
Engine:	Detroit Diesel
Transmission:	Allison Automatic
Brake Type:	ABS

[24] Obtained from DDEC report.

Figure 4 – Left Rear of 2009 Van Hool Motorcoach.

3.1 Damage Description

The rear of the motorcoach sustained most of the damage from the crash and post-crash fire – **See Figure 4**. At the front of the motorcoach, both windshield glass panes were missing, the left front was torn open exposing the driver's compartment and fuse panel, the steering wheel and dash were displaced forward toward the outside of the vehicle, and the forward portion of the left-front wheel well was displaced rearward into the steer tire. The front three cargo bay doors on the left side and the 2nd and 4th cargo bay doors on the right side of the motorcoach were missing.

3.2 Weights and Measurements

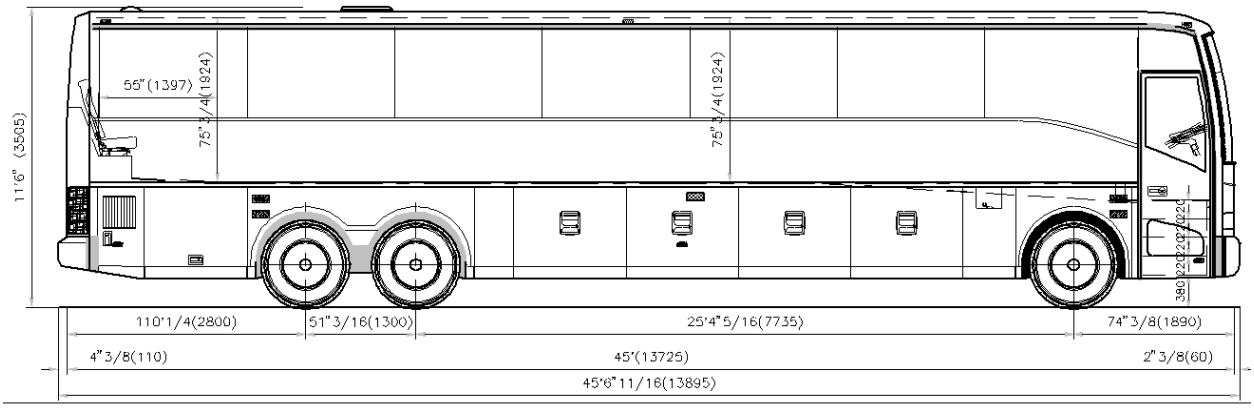

Figure 5 - Motorcoach Length, Width, and Height Measurements. Source: Van Hool

As shown in **Figure 5,** the length of the motorcoach was 45-feet 6-inches, and the height was 11-feet 6-inches. There were no axle or overall vehicle weights obtained. The vehicle was transporting 55 passengers and a driver.

3.3 Powertrain

The powertrain of the motorcoach consisted of a six-cylinder diesel engine, an automatic transmission, a drive shaft, and a rear drive axle assembly (axle 2).

The engine was mounted at the rear of the motorcoach. An examination of the engine compartment was limited due to the crash damage and post-crash fire. The majority of the combustible materials, which included the accessory drive belts, hoses, air lines, and electrical wire insulating covering, were missing from the top half of the engine.

As with the engine, the transmission was mounted at the rear of the motorcoach. The transmission was still intact and securely mounted to the engine and frame of the motorcoach. The output shaft of the transmission was connected to a short driveline via a yoke and universal joint assembly. The opposite end of the driveline was connected to the pinion gear shaft of the drive axle also via a yoke and universal joint assembly. A visual inspection of the transmission revealed no defects or malfunctions.

The drive axle housing was mounted to the motorcoach at the axle 2 location. Within the axle housing, the pinion gear transfers the rotational movement transmitted from the transmission, via the driveline, to the ring gear. The ring gear then transferred rotational movement to the two axle shafts which were connected to tires and wheels at their respective outboard ends. An inspection of the drive axle housing revealed no defects or malfunctions.

The Detroit Diesel engine was controlled by a DDEC ECM system consisting of two separate units; a Motor Control Module (MCM) and a Common Powertrain Controller (CPC). The primary function of the ECM is to control the engine's performance, fuel efficiency, and emissions based on various engine and sensor inputs. The ECM is also capable of recording diagnostics associated with engine and/or sensor faults, which may then activate warnings on the dash, as well as record vehicle speed, engine speed, and other parameters during triggered events. There is an internal clock and calendar, with an internal battery, which tracks time and stamps event-based occurrences such as hard braking incidents and last stop records. These modules were removed from the motorcoach and transported to Detroit Diesel for imaging. See the Technical Reconstruction report in the docket for additional results from the extracted data.

3.4 Driver Controls

The front of the motorcoach sustained major crash damage. The left side of the front body panel was displaced forward pulling the steering wheel and steering column away from the driver's seated position. The instrument panel, gauges, and dash area above the steering wheel were broken and displaced. The accelerator pedal was broken and lying on the floorboard. The brake pedal was distorted to the right and was wedged against the buckled floorboard.

3.5 Electrical System

The electrical system was compromised due to the crash damage and post-crash fire.

3.6 Steering System

The steering system was intact but not functional. The intermediate and lower steering shafts were separated at the slip joint. The steering was checked for looseness at the sector shaft as well as the ball joints.

3.7 Suspension

The suspension on each side of the steer axle (axle 1) of the motorcoach consisted of an independent suspension with upper and lower control arms, an air spring, and stabilizer bar connecting links connected to the stabilizer bar.

The drive axle (axle 2) of the motorcoach was a non-independent, solid axle suspension. Each side of axle 2 consisted of a shock absorber, fore and aft air springs, and a non-adjustable torque arm. There was a transversal torque arm attached to the drive-gear housing of the drive axle.

The suspension on each side of the tag axle (axle 3) consisted of an independent suspension with upper and lower control arms, a shock absorber, an air spring, and a tie rod connecting the steering knuckle to the rack and pinion rear axle steering system.

There was no pre-existing or crash damage discovered during the suspension examination.

3.8 Brake System

The complete braking system was examined. At the axle ends, the brake linings were removed from the brake calipers, measured, and examined for defects, and the brake rotors were measured and examined for defects – **See Table 5** for examination results. Due to the bus having disc brakes, no brake adjustment measurements could be taken.[25]

Table 5: Motorcoach Brake Information

Brake Location	Axle 1		Axle 2		Axle 3	
	Left	Right	Left	Right	Left	Right
Brake Type	Disc	Disc	Disc	Disc	Disc	Disc
Pushrod Stroke (Inches)	NA	NA	NA	NA	NA	NA
Measured Lining Thickness	Inboard: 16/32nds	Inboard: 16/32nds	Inboard: 25/32nds	Inboard: 24/32nds	Inboard: 9/32nds	Inboard: 13/32nds
	Outboard: 15/32nds	Outboard: 17/32nds	Outboard: 25/32nds	Outboard: 24/32nds	Outboard: 17/32nds	Outboard: 18/32nds
Rotor Measurement (inches)	1.731	1.721	1.740	1.721	1.736	1.742
Manufacturer's Specification – Minimum Rotor Thickness (inches)	1.46	1.46	1.46	1.46	1.46	1.46

There was about a 3/8-inch gap between the brake lining and shoe mounted to the inboard location on the left side of axle 3. The same brake lining was missing about a 1-inch piece on the rear bottom corner. No other defects were noted from the brake system examination.

[25] All measurements are in inches.

3.9 Tires and Wheels

The manufacturer's specification label for the motorcoach was mounted to the forward bulkhead of the stepwell. The tires and wheels specified for this vehicle were 315/80R 22.5 tires mounted on 9.00 x 22.5 wheels.

General information about each of the tires on the bus at the time of the inspection is documented in **Table 6**. All the wheels were inspected for cracks, welds, and elongated lug nut holes. No non-crash related defects were discovered on any of the wheels. Tire pressure measurements were taken using a commercial grade tire pressure gauge.

Table 6: Bus Tire Information

Axle 1	**Left**		**Right**	
Make/Model	Firestone FS 400		Firestone FS 400	
Tire Size	315/80R22.5 (L)		315/80R22.5 (L)	
Pressure	112 PSI		115PSI	
Tread Depth[26]	14,14,14,14		15,15,15,15	
DOT #	12C4D35KA4722		12C4D35KA4822	
Maximum Load Rating	9,370 lbs.		9,370 lbs.	
Tire Plies	Tread – 5 steel Sidewall – 1 steel		Tread – 5 steel Sidewall – 1 steel	
Axle 2	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Make/Model	Firestone FS 400	Firestone FS 400	Firestone FS 400	Firestone FS 400
Tire Size	315/80R22.5 (L)	315/80R22.5 (L)	315/80R22.5 (L)	315/80R22.5 (L)
Pressure	90 PSI	Deflated	90 PSI	90 PSI
Tread Depth	5,4,4,6	5,5,6,7	5,3,3,5	6,4,4,5
DOT #	4D4D35K0819	4D4D35K2019	4D4D35K2319	4D4D35K2019
Maximum Load Rating	8,820 LBS.	8,820 LBS	8,820 LBS	8,820 LBS
Tire Plies	Tread – 5 steel Sidewall – 1 steel	Tread – 5 steel Sidewall – 1 steel	Tread – 5 steel Sidewall – 1 steel	Tread – 5 steel Sidewall – 1 steel
Axle 3	**Left**		**Right**	
Make/Model	Firestone FS 400		Goodyear Marathon LHS III	
Tire Size	315/80R22.5 (L)		315/80R22.5 (L)	
Pressure	112 PSI		110 PSI	
Tread Depth	6,6,6,6		6,6,5,4	
DOT #	4D4D35K2021		WJ72CE1W1019	

[26] Measurements were taken from the outboard to inboard. Measurements are in 32nds.

Maximum Load Rating	9,370 lbs.	9,370 lbs.
Tire Plies	Tread – 5 steel Sidewall – 1 steel	Tread – 5 steel Sidewall – 1 steel

3.10 Anti-Lock Braking System (ABS)

All ABS sensors, wiring, and modulators remained intact and in place.

3.11 Maintenance Records

Maintenance records for the motorcoach were obtained from the motor carrier and from Van Hool. The maintenance records for the 12 months prior to the crash were reviewed.

- 10/7/22 Engine oil added and fixed ELD charging issue
- 12/7/2022 Oil change, new fuel filters, ABS tone rings cleaned, and 2 tires were replaced (used) (547,090 mileage)
- 12/28/2022 Replaced 2 batteries and a convex mirror. (547,909 mileage)
- 2/16/2023 Replaced brake chamber on the left side of axle 3 (555,094 mileage)
- 2/27/2023 Replaced engine oil pressure sensor (555,232 mileage)
- 3/9/2023 Replaced top brake lights, placed new tires on steer axle (560,060 mileage)
- 6/1/2023 Recharged air conditioner, secured fuel door to bus (569,823 mileage)
- 6/21/2023 Replaced brake caliper and brake pads on the left side of axle 2, replaced the brake pads on the right side of axle 2 (570,561 mileage)
- 9/27/2023 Replaced the fan clutch and corrected the ABS sensor on the right side of axle 2 (579,282 mileage)
- 10/10/2023 Replaced center exhaust manifold (580,667 mileage)
- 10/27/2023 replaced turbo charger (580,897 mileage)

4.0 Nissan Murano

Make:	Nissan
Model:	Murano SUV
VIN:	5N1AZ2MHXFNXXXXXX
Model Year:	2015
GVWR:	5,001 to 6,000 lbs.

4.1 Damage Description

The Nissan was directly behind the motorcoach at the time of impact. The Nissan was crushed between the front of the truck-tractor and the rear of the motorcoach. The Nissan sustained complete crash and post-crash fire damage, and was found in multiple pieces.[27] However, the Airbag Control Module (ACM) was located between the driver and passenger seats and removed by NTSB investigators for further analysis. The results from the ACM analysis are in the docket.

5.0 2006 Toyota Highlander

Make:	Toyota
Model:	Highlander SUV
VIN:	JTEEP21A560XXXXXX
Model Year:	2006
Date of Manufacturer:	November 2005
GVWR:	5,360 lbs.

5.1 Damage Description

The Toyota, which was traveling in front of the motorcoach, was struck at the right-rear corner by the left-front of the motorcoach. The rear lift gate, bumper, and right rear corner panel were crushed forward. The exterior door panel for the right-side rear passenger door was missing and the door was crushed. The right-front fender sustained thermal damage to the paint. The left headlamp lens was melted.

The ACM was imaged by the OSHP, and a copy was provided to the NTSB. See the Technical Reconstruction report in the docket for additional results from the extracted data.

E. DOCKET MATERIAL

The following attachments and photographs are included in the docket for this investigation:

LIST OF ATTACHMENTS

Vehicle Attachment – Vehicle Examination Photographs
Vehicle Attachment – 2019 Freightliner Build Sheets
Vehicle Attachment – Steering Gear Examination Report
Vehicle Attachment – Mid State Systems Interview Transcript

[27] See Attachment - Vehicle Examination Photographs

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